R4-NC-Brunswick

Brunswick Steam Electric Plant

2000 Environmental Monitoring Report

Environmental Services Section

BRUNSWICK STEAM ELECTRIC PLANT
2000 BIOLOGICAL MONITORING REPORT

Prepared by:

Environmental Services Section

CAROLINA POWER & LIGHT COMPANY
New Hill, North Carolina

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Preface

This copy of the report is not a controlled document as detailed in the *Environmental Services Section Biology Program Procedures Manual and Quality Assurance Manual.* Any changes made to the original of this report subsequent to the date of issuance can be obtained from:

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Table of Contents

List of Tables

List of Figures

Metric-English Conversion and Units of Measure

Length

1 micron (μm) = 4.0 x 10^{-5} inch
1 millimeter (mm) = 0.001 m = 0.04 inch
1 centimeter (cm) = 10 mm = 0.4 inch
1 meter (m) = 100 cm = 3.28 feet
1 kilometer (km) = 1000 m = 0.62 mile

Volume

1 milliliter (ml) = 0.034 fluid ounce
1 liter = 1000 ml = 0.26 gallon
1 cubic meter = 35.3 cubic feet

Area

1 square meter (m^2) = 10.76 square feet
1 hectare (ha) = 10,000 m^2 = 2.47 acres

Weight

1 microgram (μg) = 10^{-3} mg or 10^{-6} g = 3.5 x 10^{-8} ounce
1 milligram (mg) = 3.5 x 10^{-5} ounce
1 gram (g) = 1000 mg = 0.035 ounce
1 kilogram (kg) = 1000 g = 2.2 pounds
1 metric ton = 1000 kg = 1.1 tons
1 kg/hectare = 0.89 pound/acre

Temperature

Degrees Celsius (°C) = 5/9 (°F-32)

Common and Scientific Names of Species Used in this Report

Atlantic stingray	*Dasyatis sabina*
Atlantic menhaden	*Brevoortia tyrannus*
Anchovies	*Anchoa* spp.
Bay anchovy	*A. mitchilli*
Striped anchovy	*A. hepsetus*
Silversides	*Atherinidae*
Pinfish	*Lagodon rhomboides*
Star drum	*Stellifer lanceolatus*
Silver perch	*Bairdiella chrysura*
Weakfish	*Cynoscion regalis*
Spot	*Leiostomus xanthurus*
Croaker	*Micropogonias undulatus*
Striped mullet	*Mugil cephalus*
Gobies	*Gobiosoma* spp.
Gobies	*Gobiosoma* spp.
Atlantic cutlassfish	*Trichiurus lepturus*
Southern flounder	*Paralichthys lethostigma.*
Shrimp	*Penaeus* spp.
Brown shrimp	*P. aztecus*
Pink shrimp	*P. duorarum*
White shrimp	*P. setiferus*
Hardback shrimp	Trachypenaeus spp.
Swimming crab larvae	Portunid megalops
Blue crabs	*Callinectes* spp.
Blue crab	*C. sapidus*
Lesser blue crab	*C. similis*

Executive Summary

Biological monitoring of the Cape Fear Estuary (CFE) at Carolina Power & Light Company's (CP&L) Brunswick Steam Electric Plant (BSEP) was conducted in 2000 as part of the National Pollutant Discharge Elimination System (NPDES) permit requirements. Entrainment and impingement studies monitored the effectiveness of the intake modifications in reducing entrainment and impingement of fish and shellfish.

Depending upon taxa, entrainment of all organisms combined was reduced by approximately 17%, with a range of 3% to 56%, by using fine-mesh screens during 2000. Reductions in the entrainment of organisms during 2000 were similar to estimates for 1999 but less than previous years because more coarse-mesh screen panels were used. Based on survival estimates data, approximately 32% of all larval species impinged were returned alive to the estuary. Adverse effects on populations of fish and shellfish due to operation of fewer fine-mesh screens during a portion of the year was likely minimal. Results of intensive sampling throughout the 1970's, before the installation of fine-mesh screens and the fish return system, indicated that operation of the plant had no measurable adverse effect on fish and shellfish populations in the Cape Fear River Estuary.

Bay anchovy and white shrimp numerically dominated the juvenile and adult impingement catch during 2000. Prior to 1983, larger finfish such as Atlantic menhaden, spot, and croaker comprised the majority of the total weight impinged. Data collected during 2000 continued to show a shift towards impingement of smaller individuals for most species as a result of construction of the diversion structure and the use of fine-mesh screens. This is important because larger individuals comprise the reproducing members of the fish and shellfish populations. Results of time-series analysis on 24 years of data indicated significant reductions in the impingement of larger fish and shellfish as a result of the diversion structure. Ten of eleven selected taxa, including total organisms, exhibited significant decreases in impingement densities from 1977 through 2000. The impingement density of juvenile and adult Atlantic menhaden exhibited the greatest decline. Based on survival estimates, approximately 49% of the total number and 43% of the total weight of the impinged organisms, excluding bay anchovy, were returned alive to the estuary. Greater than 90% of the juvenile and adult blue crabs and approximately 87% to 94% of the shrimp were returned alive to the estuary. These were the most valuable commercial species in the CFE.

Biological monitoring during 2000 continued to show that the combination of the diversion structure, fine-mesh screens, and fish return system reduced the number of entrained and impinged fish and shellfish. These modifications also continued to ensure that the most valuable commercial species are returned alive to the estuary in large numbers.

1.0 INTRODUCTION

Carolina Power & Light Company was issued a permit in December 1974 to discharge cooling water from the BSEP into the Atlantic Ocean under a NPDES permit. Cooling water is withdrawn from the Cape Fear River (CFR). As a stipulation of the NPDES permit, biological monitoring is required to provide sufficient information for a continuing assessment of power plant impacts on the marine and estuarine fisheries of the CFE. Data are reported annually and will provide an assessment of the effectiveness of the fish diversion structure and fine-mesh screens in minimizing the entrainment and impingement of organisms.

A stipulation of the renewed 1981 NPDES permit and subsequent permits was the implementation of power plant modifications to reduce entrainment and impingement of estuarine organisms resulting from the intake of cooling water. A permanent diversion structure was constructed across the mouth of the intake canal in November 1982 to reduce impingement by preventing large fish and shellfish from entering the intake canal (Figure 1.1). To reduce entrainment, fine-mesh (1-mm) screens were installed on two of the four intake traveling screen assemblies of each unit in July 1983 and a third was installed on each unit in April 1987. Presently, the NPDES permit requires that three of the four intake traveling-screen assemblies on each unit are covered with fine mesh screens.

Under the current permit, a maximum intake flow of 26.1 cubic meters per second (cms) per unit is allowed from December through March, and 31.1 cms per unit is allowed from April through November. Normally only fine-mesh screens are used during these periods of maximum intake flow. The flow of one unit may be increased to 34.8 cms during July, August, and September by using a fourth intake pump operating with coarse-mesh (9.4-mm) screens.

Beginning in 1994, Carolina Power & Light Company reduced the biological monitoring program with the concurrence of the North Carolina Department of Environment & Natural Resources. Based on almost two decades of operation with no adverse impact on fish and shellfish populations in the CFE, the monitoring program was modified to concentrate on the impingement and entrainment of organisms (Figure 1.2). This report presents data for 2000 on impingement and entrainment rates of larval, juvenile, and adult fish and shellfish and evaluates the effectiveness of the NPDES-required plant intake modifications.

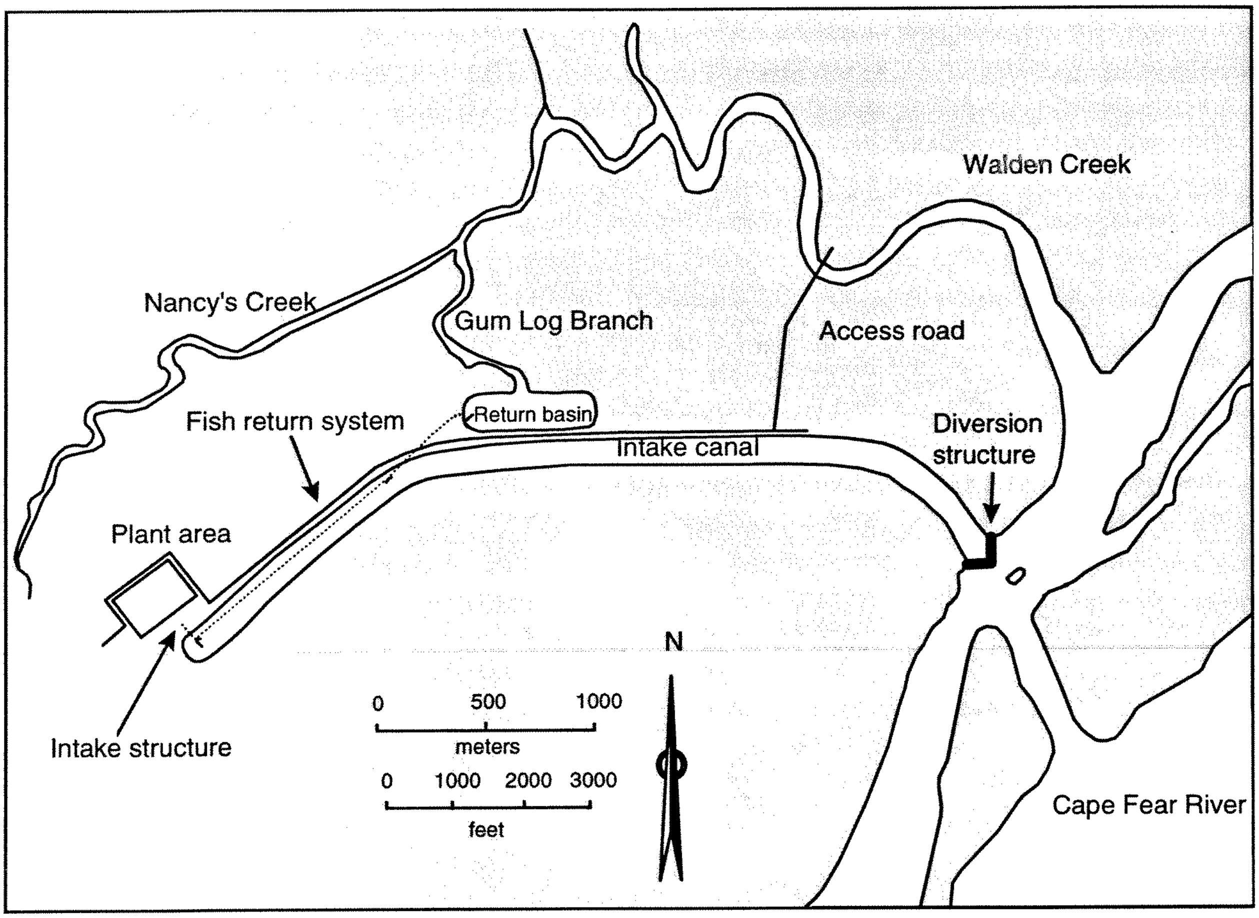

Figure 1.1 Location of fish diversion structure, fish return system, and return basin at the BSEP.

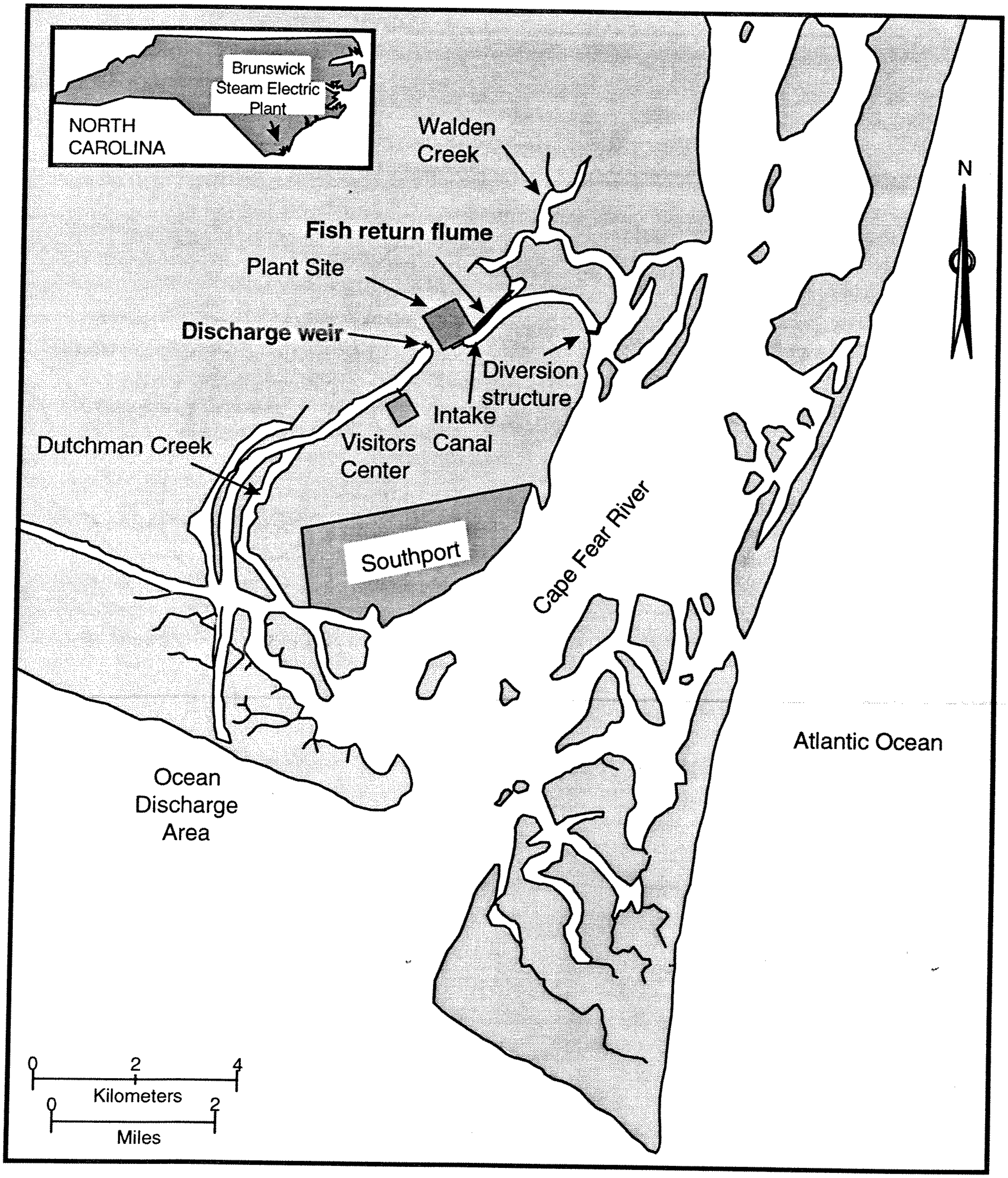

Figure 1.2 **Impingement (fish return flume) and entrainment (discharge weir) sampling locations at the BSEP during 2000.**

2.0 MONITORING PROGRAM RESULTS

2.1 Introduction

Past data indicated that the impingement of large fish and shellfish of the CFE was reduced as a result of the 9.4-mm mesh screening on the diversion structure (CP&L 1984, 1985a, 1985b). Organisms small enough to enter the intake canal through the diversion structure may be impinged on the plant intake screens and returned to the CFE via a fish-return flume or they may be entrained through the plant. Previous studies by CP&L have documented a reduction in the entrainment of small organisms due to installation of fine-mesh screens at the intake structure and the subsequent survival of a percentage of impinged larvae returned to the CFE via the fish-return flume (Hogarth and Nichols 1981; CP&L 1989).

Entrainment sampling during 2000 documented the species composition, seasonality, and abundances of larval and postlarval organisms passing through the cooling system. Larval ? impingement sampling evaluated the success of the fine-mesh screens in reducing entrainment of these organisms. Juvenile and adult (J/A) impingement sampling documented species composition, densities, weights, and lengths of juvenile and adult organisms impinged during 2000 and provided evidence of the continued effectiveness of the diversion structure. Survival study results from previous years were used to determine the effectiveness of the return system for returning impinged organisms alive to the CFE (CP&L 1987, 1988).

2.2 Methods

The collection gear for entrainment and impingement has remained unchanged since 1984 (CP&L 1985a). Because sampling was conducted only once per month since 1990, results were not expanded to obtain annual estimates of organisms entrained or impinged; rather, entrainment and impingement rates, densities, and total number of organisms collected were expanded to give an estimate for 24 hours. The juvenile and adult impingement program included fish and shrimp ≥ 41 mm, portunid crabs ≥ 25 mm, and eels and pipefish ≥ 101 mm. Individuals smaller than these limits were included in the larval impingement program.

Densities calculated for all larval organisms were averaged to obtain a mean number per 1000 m^3 of water entrained through the plant per sampling date. Densities for juvenile and adult organisms impinged on each sampling date were calculated by dividing the total number of organisms collected by the volume of water pumped through the plant. Densities were expressed as the number per million cubic meters of water pumped through the plant during each 24-hour sampling period.

Time-series analysis (ln [density + 1]; CP&L 1985a) was performed on juvenile and adult impingement data from January 1977 through December 2000. Selected species included bay anchovy, Atlantic menhaden, croaker, spot, weakfish, southern flounder, brown shrimp, pink shrimp, white shrimp, and blue crabs (*Callinectes* spp.). The 1983 data were excluded from analysis because impingement samples were not collected during July through December of that year. One sampling trip per month was used for all years for comparable sampling effort.

Survival was determined for selected size classes of the dominant organisms that have been impinged at the BSEP in past years (CP&L 1985a, 1986, 1987, 1988). Screens were operated on slow-screen rotation speed (75 cm/min) for most sampling dates in 2000. Survival estimates were calculated using survival rates determined during previous studies for slow-screen rotation (CP&L 1987, 1988). A mortality rate of 100% was used for taxa that have never been tested. Thus, the estimated survival rate for total organisms is a conservative and minimum estimate.

2.3 Results and Discussion

2.3.1 Dominant Species

Croaker was the most abundant species collected in entrainment samples during 2000 and comprised 35.8% of all organisms collected (Table 2.1). *Gobiosoma* spp. (23.3%) was the second most abundant followed by spot (12.7%). Other taxa entrained (in decreasing order of abundance) were *Anchoa* spp, (≥ 13 mm), *Penaeus* spp., *Anchoa* spp. (< 13 mm), portunid megalops, silversides, Atlantic menhaden, and pinfish. Additional taxa comprised 4.5% of the total collected. The cumulative density of total organisms collected in entrainment samples during 2000 was 46.8% greater than that collected during 1999 (Table 2.1; CP&L 2000).

The cumulative density of croaker collected during entrainment sampling increased during 2000 compared to 1999 due to operation of coarse-mesh screens during February and a greater population of croaker residing in the lower estuary as a result of high freshwater input to the estuary during February (Table 2.11 and Figure 2.1). Croaker normally resides in greater abundance in the upper Cape Fear Estuary. However, elevated freshwater flow during February restricted many larval croaker to the lower estuary. Elevated freshwater input during the recruitment period of many species has been shown to limit movement to the upper estuary (Copeland et al. 1979; Lawler et al. 1988; Rogers et al. 1984; Thompson 1989; Weinstein et al. 1980a, 1980b).

Ten taxa accounted for 94.9% of the total larval organisms collected in impingement samples during 2000. *Gobiosoma* spp. (25.8%) was the most dominant taxa collected. Although the relative ranking has varied, the ten most abundant species have generally dominated larval impingement samples each year since 1984. The number of larvae collected during larval impingement sampling during 2000 increased by 9.1% compared to 1999 (Table 2.2; CP&L 2000). The number of larval taxa collected in impingement samples was generally greater than the number collected in entrainment samples (Figure 2.2).

Ten taxa accounted for 92.1% of the total number of organisms collected in J/A impingement samples during 2000 (Table 2.3). Bay anchovy was the most numerous species impinged, accounting for 49.2% of the total number impinged during 2000. White shrimp was the second most abundant taxa impinged, accounting for 9.4% of the total number collected. Prior to intake modifications in 1983, Atlantic menhaden numerically dominated J/A impingement samples (CP&L 1980a, 1980b, 1982, 1983). Striped anchovy, brown shrimp, spot, lesser blue crab, blue crab, Atlantic menhaden, star drum, and Atlantic silversides combined accounted for an additional 33.5% of the total number collected. These ten most abundant taxa comprised 83.4% of the total weight collected during impingement sampling. Other taxa that contributed substantially to the biomass collected during J/A impingement sampling were Atlantic cutlassfish (19.8 kg), pinfish (6.3 kg), striped mullet (5.1 kg), silver perch (3.5 kg), Atlantic stingray (3.4 kg), and southern flounder (3.4 kg).

2.3.2 Seasonality and Abundance

Seasonal variations for the larvae of selected species entrained in 2000 were similar to those observed in previous years and corresponded to the seasonalities of larval fish in the CFE (Tables 2.4 and 2.5; CP&L 1994). Peaks of abundance in entrainment and impingement of organisms can be influenced by environmental conditions such as changing freshwater discharge to the estuary, operating screens without fine mesh, increasing or decreasing the flow of cooling water as determined by plant operational needs, and sampling period.

The typical winter and summer periods of abundance observed during 2000 in the entrainment program were also observed in the larval impingement program (Table 2.6). Atlantic menhaden, spot, croaker, and pinfish--all ocean-spawned species--were most abundant during the winter and spring months. Shrimp larvae were most abundant during spring and mid-summer. Estuarine-spawned species (e.g. anchovy, *Gobiosoma* spp., and silversides) were most abundant during summer. The period of abundance for portunid megalops occurred during the fall. Larval *Gobionellus* spp., present year-round, were most abundant during spring.

Seasonalities of larger individuals collected during J/A impingement sampling were consistent with previous years and to the natural seasonalities reported for these species by Schwartz et al. (1979) in the lower CFE and near-shore ocean. Atlantic menhaden abundant during the winter were yearlings as indicated by modal lengths of 85 mm and 90 mm (Tables 2.7 and 2.8). During December, the majority of Atlantic menhaden impinged were young-of-year individuals. Yearling fish comprised the majority of spot collected during January and February. Peak densities of croaker during February were associated with yearling individuals while young-of-year individuals comprised the majority of the croaker collected during April. Bay anchovy was most abundant from January through April and November through December. Peak densities of white, brown, and pink shrimp occurred during the summer and fall. Blue crab was most abundant during summer.

Installation of the diversion structure has resulted in a decline in the impingement densities of most J/A organisms. Results of time-series analysis indicated that total organisms and nine of the ten selected taxa exhibited significant decreases in impingement density over the past 24 years (Table 2.9). Atlantic menhaden exhibited the greatest decline in impingement density (Figure 2.3). White shrimp was the only species that exhibited a significant increase in density over the study period (Table 2.9 and Figure 2.4). This trend was a result of a natural increase in white shrimp populations in the CFE. Previous studies have shown that significant increases in the white shrimp population in Walden Creek coincide with increases in impingement of this species (CP&L 1994). Postlarval shrimp too small to be excluded by the diversion structure successfully recruited to the intake canal and used it as nursery habitat and were subsequently impinged (Birkhead et al. 1979; Copeland et al. 1974, 1979; CP&L 1991).

2.3.3 Flow Rates

The amount of water pumped through the plant can affect the number and weight of organisms impinged and entrained. Monthly intake flow volumes during 2000 ranged from 93 million m^3 in March to 176 million m^3 in August (Figure 2.5). The mean monthly flow volume during 2000 was higher than the mean flows of previous years including the period 1977-1982 when there were less stringent flow-minimization requirements. The greater monthly volumes during 2000 were a result of the significantly reduced time required for outages resulting in more continuous plant operation. The low monthly volume during March was a result of the Unit 1 refueling outage.

2.3.4 Fine-Mesh Screens

Entrainment and larval impingement rates per 24-hour sampling period during 2000 were summed to find the total number of larvae affected. The percent effectiveness (how successfully the organisms were kept from being entrained) of fine-mesh screens was calculated as the ratio between the larval impingement rate and the total number (entrainment plus larval impingement) affected for each sampling trip. The overall effectiveness for total organisms ranged from 8% to 44% when data from all sampling trips were analyzed (Table 2.10). These efficiencies were similar to those reported for 1999 but less than the 7% to 58% reported for 1998 when fewer coarse-mesh screen panels were operated (CP&L 1999, 2000). Previous studies have shown that the operation of three fine-mesh screens per unit versus no fine-mesh screens may reduce the total mean density of entrained organisms by 61% (CP&L 1989, 1998).

The reduced efficiencies were a result of operation of one or more coarse-mesh traveling screens and some screens with 50% of the fine-mesh panels removed during portions of the year (Table 2.11). During periods of high vulnerability resulting from extreme lunar tides or increased sediment and debris loading, the NPDES permit allows for removal of a portion of the fine-mesh screens to prevent plant scrams. High vulnerability conditions existed for most of the year. However, by November, all of the fine-mesh traveling screens had been restored (Table 2.11). The root cause of previous clogging events was determined to be the result of detritus and mud accumulation on the traveling screens during extreme low tides coupled with increased sedimentation (due to recurring hurricanes in recent years) resulting in shoaling of the intake canal. Fouling of plant operating systems by marine macroalgae (*Gracilaria* spp.) also became significant during the latter part of 2000.

In addition to the number of fine-mesh screens operating, the variability of effectiveness was influenced by species composition, seasonality, and organism size. Body size and shape have been shown to have an effect on screening efficiency for other species of larval fish (Tomljanovich et al. 1978; Stone & Webster Engineering Corporation 1984). During March, November, and December when fine-mesh screen efficiencies were highest, no or fewer coarse-mesh screens were operating and the dominant larvae were croaker, spot, Atlantic menhaden, *Anchoa* spp. (≥ 13 mm), *Penaeus* spp. and portunid megalops (taxa exhibiting relatively high fine-mesh screen efficiency) (Tables 2.5, 2.6 and 2.10). The lowest fine-mesh screen efficiencies for the year were recorded during January, February, and September when greatest numbers of coarse-mesh screens were in operation (Table 2.10). Despite the operation of fewer fine-mesh traveling screens during 2000, the number of larval taxa collected during impingement sampling was greater than the number collected in entrainment samples for most months of the year (Figure 2.2).

Adverse effects on populations of fish and shellfish due to operation of fewer fine-mesh screens during a portion of the year was likely minimal. Results of intensive sampling throughout the 1970's, before the installation of fine-mesh screens and the fish return system, indicated that operation of the plant had no measurable adverse effect on fish and shellfish populations in the Cape Fear River Estuary (CP&L 1980a). Annual population levels were determined by temperature, freshwater flow, and salinity (CP&L 1980a).

2.3.5 Survival Estimates

Eight of the most commonly impinged larval taxa were previously tested for survival on slow screen rotation speed (Table 2.12). These eight taxa accounted for 61.1% of the total larval impingement catch. Survival during slow-screen rotation ranged from 0% for Atlantic menhaden to 86.3% for portunid megalops. Approximately 35.2% of the selected organisms were returned alive to the estuary. Estimates indicated that approximately 31.7% of all the larval taxa impinged were returned to the estuary alive.

Six taxa of the dominant J/A organisms impinged were previously tested for survival during slow-screen rotation (Table 2.13; CP&L 1987, 1988). These taxa accounted for 78.9% of the total number collected and 58.1% of the total weight collected. Excluding bay anchovy, survival ranged from 53.1% for croaker to 92.1% for blue crabs. The most valuable commercial species (shrimp and blue crabs) exhibited the highest survival rates. Survival estimates indicated that 48.9% of the total number and 43.4% of the total weight of the selected J/A organisms impinged, excluding bay anchovy, were returned alive to the estuary during 2000. These percentages were less than reported for 1999 (76.0% and 73.4%, respectively) since fewer penaeid shrimp and blue crabs were collected during 2000 (Table 2.3; CP&L 2000). Relatively low freshwater flow during the summer and fall likely resulted in the impingement of fewer shrimp and blue crab. Historical data has indicated that relatively low freshwater flow during the recruitment period of a particular species will result in a greater abundance of individuals in the portion of the estuary upriver of the BSEP (CP&L 1994; Copeland et al 1979; Lawler et al 1988; Thompson 1989; Weinstein et al 1980a, 1980b)

2.4 Summary and Conclusions

Seasonalities of organisms collected in the 2000 entrainment and larval impingement studies were similar to previous years and corresponded to seasonalities of larval organisms in the CFE. Croaker was the most abundant organism collected in entrainment samples and Gobiosoma spp. was the most abundant taxa collw larval impingement samples. The total mean density of organisms collected in entrainment samples increased approximately 47 % from that collected in 1999. The total number of larval organisms collected in impingement samples increased by 9% from the total number collected during 1999. These increases were likely the result of a greater abundance of postlarval croaker in the lower estuary and the use of less fine-mesh screening during 2000.

Use of fine-mesh screens reduced the number of larval organisms and the number of larval taxa collected during entrainment sampling. Depending upon taxa, entrainment of all organisms was reduced by approximately 17% with a range of 3% to 56% by using fine-mesh screens in 2000. Reductions in the entrainment of organisms during 2000 were similar to 1999 but less than previous years because fewer fine-mesh screen panels were operated. Adverse effects on populations of fish and shellfish due to operation of fewer fine-mesh screens during a portion of the year was likely minimal. Results of intensive sampling throughout the 1970's, before the installation of fine-mesh screens and the fish return system, indicated that operation of the plant had no measurable adverse effect on fish and shellfish populations in the Cape Fear River Estuary. Annual population levels during recruitment to the estuary were determined by temperature, freshwater flow, and salinity. Based on survival estimates data, approximately 32% of all larval species impinged were returned alive to the estuary.

Increased sedimentation rates during recent years contributed to operability problems with the fine-mesh traveling screens during 1999 and 2000. Several cooling water pump trips have occurred during the past two years including one reactor scram in late June 1999 requiring the removal of some fine-mesh screen panels. Maintenance dredging of the intake canal is underway in an effort to restore full operability of the fine-mesh traveling screens and plant personnel monitor the conditions of the intake canal and associated plant operating systems on a daily basis.

Bay anchovy and white shrimp numerically dominated the juvenile and adult impingement catch during 2000. Prior to 1983, larger finfish such as Atlantic menhaden, spot, and croaker comprised the majority of the total weight impinged. Data collected during 2000 continued to show a shift towards impingement of smaller individuals for most of the selected species as a result of the construction of the diversion structure and the use of fine-mesh screens. This is important because larger individuals comprise the reproducing members of the population. Results of time-series analysis on 24 years of data indicated significant reductions in the impingement of larger fish and shellfish as a result of the diversion structure. Ten of eleven selected taxa, including total organisms, exhibited significant decreases in impingement densities from 1977 through 2000. The impingement density of juvenile and adult Atlantic menhaden exhibited the greatest decline. Based on survival estimates, approximately 49% of the total number and 43% of the total weight of the impinged organisms, excluding bay anchovy, were returned alive to the estuary. Greater than 90% of the blue crabs and 87% to 94% of the shrimp impinged during 2000 were returned alive to the estuary. These were the most valuable commercial species.

Modifications made to the Brunswick Steam Electric Plant intake continued to be effective in reducing the number of organisms affected by the withdrawal of cooling water from the Cape Fear Estuary. The diversion structure excluded most large organisms and many of the larval, juvenile, and adult organisms impinged were returned alive to the estuary by using fine-mesh traveling screens and the fish return system.

Table 2.1 **Cumulative density (No./1000 m^3) and percent of total for fish, penaeid shrimp, and portunid megalops collected during entrainment sampling at the BSEP during 1999 and 2000 (based on ranking for 2000).**

	1999		2000	
Taxon	**Cumulative+ density**	**Percent**	**Cumulative+ density**	**Percent**
Croaker	1,267	14.4	4,615	35.8
Gobiosoma spp.	3,308	37.7	3,004	23.3
Spot	1,101	12.6	1,638	12.7
Anchoa spp. (≥ 13 mm)	326	3.7	1,147	8.9
Penaeus spp.	715	8.2	646	5.0
Anchoa spp. (<13 mm)	610	7.0	360	2.8
Portunid megalops	404	4.6	357	2.8
Silversides	207	2.4	283	2.2
Atlantic menhaden	28	0.3	130	1.0
Pinfish	68	0.8	129	1.0
Other taxa	479	5.5	575	4.5
Total¶	**8,774**	**100.0**	**12,883**	**100.0**

+ Cumulative density is the sum of the twelve sampling-day mean densities.

¶ Total may vary from summation due to rounding of individual taxon.

Table 2.2 Total number of the ten most abundant taxa estimated for larval impingement sampling at the BSEP during 2000, ranked by percent.

Taxon	Total number+	Percent
Gobiosoma spp.	3.2×10^6	25.8
Croaker	2.0×10^6	15.9
Spot	1.7×10^6	13.8
Penaeus spp.	1.4×10^6	11.2
Portunid megalops	1.2×10^6	9.9
Anchoa spp. (<13 mm)	8.7×10^5	7.0
Anchoa spp. (≥13 mm)	7.4×10^5	6.0
Atlantic menhaden	4.2×10^5	3.4
Gobionellus spp.	1.2×10^5	1.0
Pinfish	1.1×10^5	0.9
Other taxa	0.6×10^6	5.1
Total¶	$\mathbf{1.2 \times 10^7}$	**100.0**

+Total number is a sum of the twelve sampling-day totals.

¶Total may vary from summation due to rounding of individual taxon.

Table 2.3 **Total number, total weight, and percent of total of the ten most abundant juvenile and adult organisms collected in the BSEP impingement samples during 2000.**

Taxon	Number+	Percent¶	Weight (kg)+	Percent¶
Bay anchovy	46,844	49.2	48.3	10.1
White shrimp	8,939	9.4	57.3	12.0
Striped anchovy	7,700	8.1	35.2	7.4
Brown shrimp	7,501	7.9	41.4	8.7
Spot	4,816	5.1	52.1	10.9
Lesser blue crab	3,533	3.7	13.1	2.7
Blue crab	2,706	2.8	90.8	19.0
Atlantic menhaden	2,401	2.5	50.1	10.5
Star drum	1,814	1.9	5.6	1.2
Atlantic silversides	1,394	1.5	4.4	0.9
Other taxa	7,618	7.9	79.5	16.6
Total	**95,265**	**100.0**	**477.7**	**100.0**

+Numbers and weights are sums of the twelve sampling day totals.

¶Percentages may not add up to 100 due to rounding.

Table 2.4 Entrainment densities (mean no./1000 m^3 per sampling day) of selected taxa+ at the BSEP during 2000.

Taxa	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Portunid megalops	0	0	3	42	6	5	18	13	77	32	117	44
Penaeus spp.	52	0	61	215	23	27	72	63	125	2	6	0
Croaker	861	3150	187	118	0	0	0	0	8	2	19	271
Anchoa spp. (<13 mm)	0	0	0	0	113	111	52	72	12	0	0	0
Anchoa spp. (≥ 13 mm)	329	101	26	10	18	171	18	91	151	64	3	260
Spot	15	1,111	414	98	0	0	0	0	0	0	0	0
Gobionellus spp.	3	3	11	52	0	0	1	11	6	0	0	22
Gobiosoma spp.	3	0	0	0	354	2,204	204	151	83	4	0	0
Silversides	0	0	0	141	139	3	0	0	0	0	0	0
Atlantic menhaden	6	7	110	3	0	0	0	0	0	0	0	3
Pinfish	3	18	49	30	0	0	0	0	0	0	0	28
Total organisms	**1,269**	**4,386**	**883**	**719**	**792**	**2,595**	**391**	**436**	**511**	**102**	**146**	**653**

+Selected taxa comprised ≥ 1% of the total sampled in either entrainment or larval impingement.

Table 2.5 Entrainment rates (million per sampling day) of selected taxa⁺ at the BSEP during 2000.

Taxa	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Portunid megalops	0	0	0.007	0.225	0.032	0.025	0.104	0.072	0.441	0.174	0.629	0.199
Penaeus spp.	0.234	0	0.137	1.160	0.122	0.146	0.411	0.359	0.713	0.008	0.034	0
Croaker	3.884	14.21	0.422	0.637	0	0	0	0	0.044	0.009	0.104	1.221
Anchoa spp. (< 13 mm)	0	0	0	0	0.609	0.595	0.298	0.411	0.070	0	0	0
Anchoa spp. (≥ 13 mm)	1.486	0.458	0.058	0.054	0.098	0.918	0.102	0.519	0.860	0.343	0.016	1.174
Spot	0.068	5.014	0.933	0.528	0	0	0	0	0	0	0	0
Gobionellus spp.	0.013	0.015	0.025	0.277	0	0	0.008	0.061	0.036	0	0	0.099
Gobiosoma spp.	0.014	0	0	0	1.907	11.865	1.166	0.861	0.470	0.024	0	0
Silversides	0	0	0	0.759	0.750	0.017	0	0	0	0	0	0
Atlantic menhaden	0.028	0.032	0.248	0.018	0	0	0	0	0	0	0	0.014
Pinfish	0.013	0.081	0.112	0.162	0	0	0	0	0	0	0	0.128
Total organisms	**5.725**	**19.790**	**1.993**	**3.870**	**4.266**	**13.969**	**2.228**	**2.485**	**2.911**	**0.550**	**0.783**	**2.946**
Volume (x10^6 m^3)	**4.512**	**4.512**	**2.256**	**5.383**	**5.383**	**5.383**	**5.701**	**5.701**	**5.701**	**5.383**	**5.383**	**4.512**

⁺Selected taxa comprised ≥ 1% of the total sampled in either entrainment or larval impingement.

Table 2.6 Total number (million per sampling day) of selected taxa+ estimated by monthly samples of larval impingement at the BSEP during 2000.

Taxa	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Portunid megalops	0.021	0	0.022	0.073	0.053	0.036	0.119	0.065	0.086	0.062	0.362	0.325
Penaeus spp.	0.049	0	0.184	0.197	0.124	0.029	0.328	0.292	0.129	0.015	0.030	0.004
Croaker	0.314	0.944	0.148	0.161	0.001	0	0	0	0.001	0.004	0.034	0.359
Anchoa spp. (< 13 mm)	0	0	0	0	0.751	0.084	0.006	0.023	0.002	< 0.001	0	0
Anchoa spp. (≥ 13 mm)	0.013	0.035	0.011	0.002	0.021	0.107	0.007	0.015	0.012	0.038	0.017	0.462
Spot	0.038	0.891	0.699	0.080	0.002	0	0	0	0	0	0	0
Gobionellus spp.	0.005	0.002	0.029	0.057	0.009	0	0.007	0.007	0	0.002	0.001	0.003
Gobiosoma spp.	0	0	0	0	0.584	2.470	0.095	0.017	0.016	0.007	0	0
Silversides	0	0	0	0.018	0.019	0.003	0	0.001	0	0	0	0
Atlantic menhaden	0.001	0.004	0.413	0.002	0	0	0	0	0	0	0	0.005
Pinfish	0.016	0.016	0.050	0.009	0	0	0	0	0	0	0.002	0.021
Total organisms	**0.467**	**1.927**	**1.572**	**0.642**	**1.691**	**2.841**	**0.620**	**0.488**	**0.267**	**0.151**	**0.449**	**1.246**

+Selected taxa comprised ≥ 1% of the total sampled in either entrainment or larval impingement.

Table 2.7 Juvenile and adult impingement densities (No./million m^3 of water entrained during each 24-hour sampling period) for selected species+ per month at the BSEP during 2000.

Month	Bay anchovy	Atlantic menhaden	Spot	Croaker	White shrimp	Brown shrimp	Pink shrimp	Blue crab
Jan	2,432	147	480	8	174	0	0	4
Feb	608	206	284	11	0	0	0	0
Mar	530	3	4	0	10	0	0	94
Apr	2,170	108	41	11	14	5	1	195
May	91	10	31	6	1	22	7	150
Jun	17	4	11	8	0	987	0	193
Jul	0	0	7	0	8	293	16	39
Aug	1	< 1	11	2	877	29	4	196
Sep	105	0	0	5	394	27	34	215
Oct	187	0	6	< 1	61	0	8	70
Nov	2,195	0	0	< 1	36	10	2	19
Dec	1,384	31	173	7	53	0	0	17

+Selected species, with the exception of bay anchovy, are commercially and recreationally important species that accounted for greater than 1% of the total catch by number or weight.

Table 2.8 Modal lengths (mm) for selected+ juvenile and adult impingement species¶ collected by month at the BSEP during 2000.

Month	Atlantic menhaden	Spot	Croaker	White shrimp	Brown shrimp	Pink shrimp
Jan	85	75	ID£	55	NC§	NC
Feb	80	80	ID	NC	NC	NC
Mar	ID	80	NC	60	NC	NC
Apr	90	40	55, 60	130	ID	ID
May	45	50	60, 65	ID	50	105
Jun	ID	45	ID	NC	70	NC
Jul	NC	105	NC	60	105	65,70
Aug	ID	65	ID	110	85	65
Sep	NC	NC	170	90	80	50
Oct	NC	165	ID	105	NC	60
Nov	NC	NC	ID	110	ID	ID
Dec	65	65	ID	95	NC	NC

+Selected species are commercially and recreationally important species which accounted for greater than 1% of the total catch by number or weight.

¶Fish ≥ 41 mm and crabs ≥ 25 mm.

§NC= None Collected.

£ID = Insufficient number collected (< 10).

Table 2.9 Time-series analysis of BSEP juvenile and adult impingement data indicating trends in density [ln(nu./million m^3+1)] from January 1977 through December 2000.

Taxon	Trend+	Slope	R^2
Atlantic menhaden	–***	–0.00043	0.97
Weakfish	–***	–0.00025	0.97
Blue crabs	–***	–0.00019	0.96
Spot	–***	–0.00012	0.96
Croaker	–***	–0.00023	0.96
Southern flounder	–***	–0.00016	0.96
Pink shrimp	–***	–0.00018	0.96
Bay anchovy	– ***	–0.00009	0.98
Brown shrimp	– **	–0.00005	0.97
White shrimp	+***	0.00030	0.98
Total organisms	–***	**–0.00015**	**0.96**

+Trends are explained with the following notation:

NS = $P > 0.05$
* = $0.01 < P \leq 0.05$
** = $0.001 < P \leq 0.01$
*** = $P \leq 0.001$
+ = Increasing trend
– = Decreasing trend

R^2 = Amount of variation explained by the dependent variable in the time-series model.

Table 2.10 **Percent effectiveness of fine-mesh screens in reducing the number of selected taxa entrained per sampling day at the BSEP during 2000.**

Taxa	Month												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Annual**
Portunid megalops	100	NP+	76	24	62	59	53	47	16	26	37	62	**39**
Penaeus spp.	17	NP	57	15	51	17	44	45	15	65	47	100	**29**
Croaker	7	6	26	20	100	NP	NP	NP	2	31	25	23	**9**
Anchoa spp. (< 13 mm)	NP	NP	NP	NP	55	12	2	5	2	100	NP	NP	**30**
Anchoa spp. (≥ 13 mm)	1	7	15	3	17	10	6	3	1	10	53	28	**11**
Spot	36	15	43	13	100	NP	NP	NP	NP	NP	NP	NP	**21**
Gobionellus spp.	27	10	54	17	100	NP	45	11	0	100	100	3	**19**
Gobiosoma spp.	0	NP	NP	NP	23	17	8	2	3	23	NP	NP	**16**
Silversides	NP	NP	NP	2	2	15	NP	100	NP	NP	NP	NP	**3**
Atlantic menhaden	3	11	62	10	NP	NP	NP	NP	NP	NP	NP	26	**56**
Pinfish	55	16	31	5	NP	NP	NP	NP	NP	NP	100	14	**19**
Total Organisms	**8**	**9**	**44**	**14**	**28**	**17**	**22**	**16**	**8**	**22**	**36**	**30**	**17**

+NP = Not Present.

Table 2.11 Number of main cooling-water pumps and fine-mesh screens operating by sampling date[+] at the BSEP during 2000.

Date	Number of pumps	Number of Fine-mesh traveling screens[¶]
January 18-19	6	1 fine mesh screen & 2 coarse mesh screens per unit
February 8-9	6	Unit 1-1 fine mesh & 2 coarse mesh screens; Unit 2-2 fine mesh & 1 coarse mesh screen
March 6-7	3	2 fine mesh screens & 1 coarse mesh screen (Unit 1 refueling outage)
April 11-12	6	2 fine mesh screens & 1 coarse mesh screen per unit
May 17-19	6	2 fine mesh screens & 1 coarse mesh screen per unit
June 13-14	6	Unit 1-2 fine mesh & 1coarse mesh screen; Unit 2-1 fine mesh, 1 50% fine mesh, & 1 coarse mesh screen
July 19-20	7	Unit 1-2 fine mesh & 1coarse mesh screen; Unit 2-2 fine mesh, 1 50% fine mesh, & 1 coarse mesh screen
August 16-17	7	Unit 1-2 fine mesh & 1coarse mesh screen; Unit 2-2 fine mesh, 1 50% fine mesh, & 1 coarse mesh screen
September 20-21	7	Unit 1-2 fine mesh, 1 50% fine mesh, & 1coarse mesh screen; Unit 2-2 fine mesh, & 1 coarse mesh screen
October 18-19	6	2 fine mesh screens & 1 50% fine mesh screen per unit
November 14-15	6	All fine mesh screens
December 11-12	6	All fine mesh screens

[+]Fine-mesh screen configurations represent those in effect during the 24-hour sampling trip.

[¶]The NPDES permit allows for a fine-mesh traveling screen to be switched with a coarse-mesh screen for routine maintenance or during periods of high vulnerability from potential clogging.

Table 2.12 Estimated number and percent survival of selected larval organisms collected during impingement sampling at the BSEP during 2000.

Taxon	Number collected	Percent survival+	Number survived¶
Croaker	1,966,320	14.4	283,150
Spot	1,709,280	9.0	153,835
Penaeus spp.	1,381,104	80.3	1,109,027
Portunid megalops	1,221,840	86.3	1,054,448
Anchoa spp. (≥ 13 mm)	738,432	0.3	2,215
Atlantic menhaden	424,656	0.0	0
Hardback shrimp	89,424	48.4	43,281
Blue crabs	10,224	94.0	9,611
Total selected taxa	**7,541,280**	**35.2**	**2,655,567**
Total all taxa§	**12,359,088**	**31.7**	**3,918,957**

+Reference: CP&L 1987 and 1988 (slow-screen rotation).

¶The number survived is a total for the 12 sampling days and not the entire year.

§Survival estimate is for all taxa including those not tested for survival during slow-screen rotation. This estimate is very conservative in that 100% mortality is assumed for taxa not tested. In reality, many of these individuals survived.

Table 2.13 Estimated number, weight (kg), and percent survival of selected juvenile and adult organisms collected during impingement sampling at the BSEP during 2000.

Taxon	Number collected	Weight collected	Percent survival[+]	Number[¶] survived
Bay anchovy	46,844	48.3	1.1	515
Shrimp (pink and white)	9,514	58.6	86.5	8,230
Brown shrimp	7,501	8.7	90.7	6,803
Blue crabs	6,239	103.8	92.1	5,746
Spot	4,816	52.1	57.1	2,750
Croaker	300	6.2	53.1	159
Total	**75,214**	**277.7**		**24,204**
Percent survival[§] (all species)	**25.4% by number**	**39.3% by weight**		
Percent survival[§] (all species excluding bay anchovy)	**48.9% by number**	**43.4% by weight**		**23,689**

[+]Reference: CP&L 1988 (Slow-screen rotation).

[¶]The number survived is a total for the 12 sampling days and not the entire year.

[§]Survival estimate is for all taxa including those not tested for survival during slow-screen rotation. This estimate is very conservative in that 100% mortality is assumed for taxa not tested. In reality, many of these individuals survived.

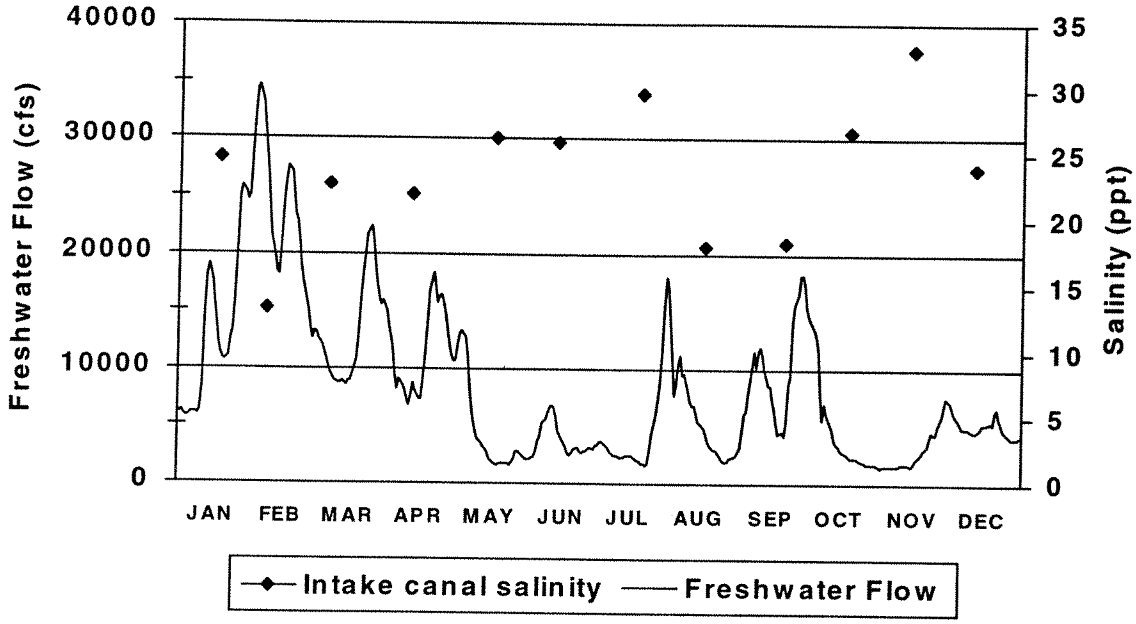

Figure 2.1 Mean daily freshwater flow to the Cape Fear River and intake canal salinity at the BSEP during 2000.

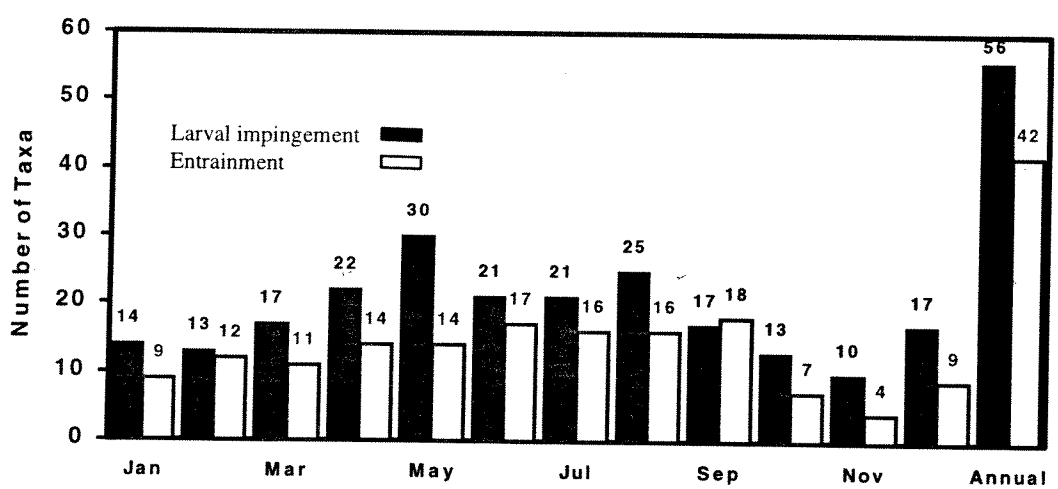

Figure 2.2 Number of taxa collected in entrainment and larval impingement samples at the BSEP during 2000.

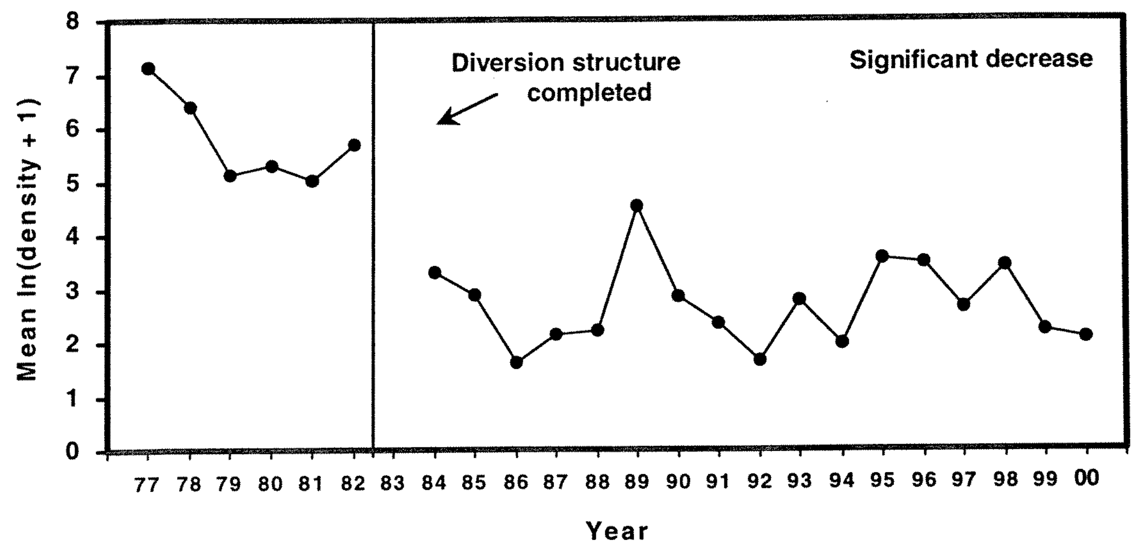

Figure 2.3 Time-series analysis of juvenile and adult Atlantic menhaden data collected during impingement sampling at the BSEP from 1977 through 2000.

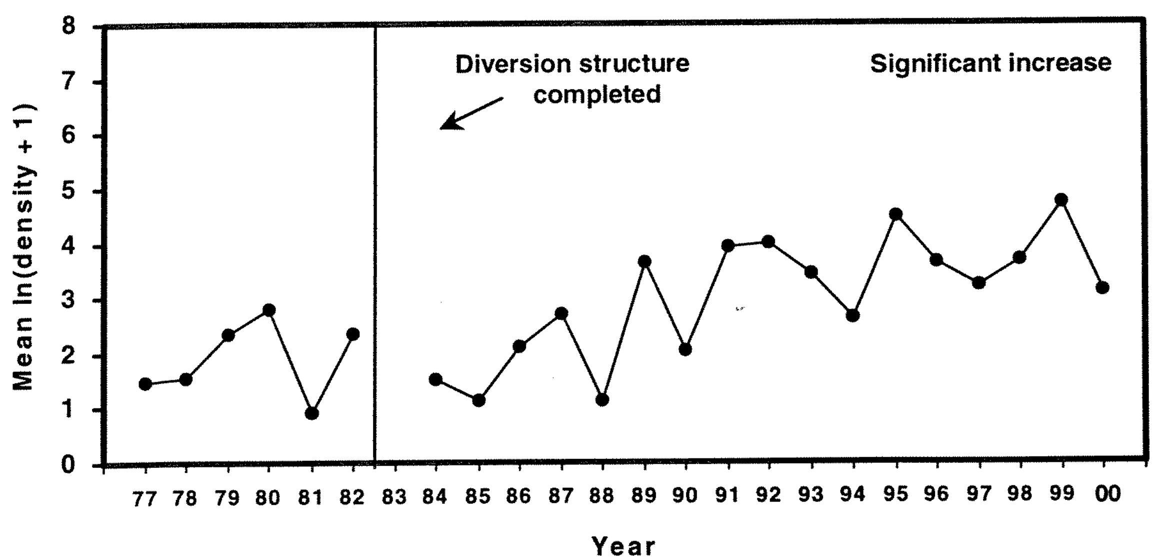

Figure 2.4 Time-series analysis of juvenile and adult white shrimp data collected during impingement sampling at the BSEP from 1977 through 2000.

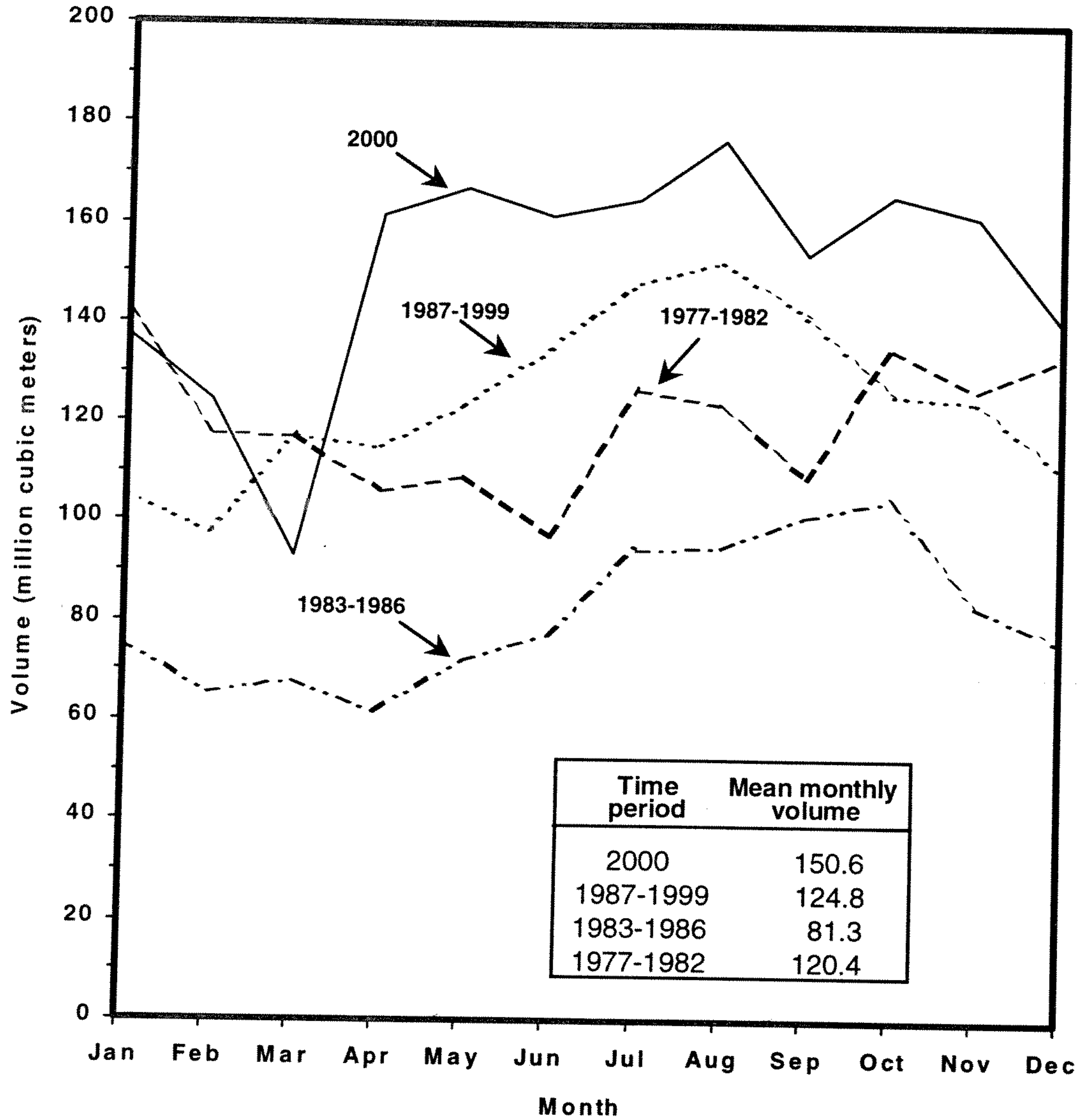

Figure 2.5 **Monthly volume (million cubic meters) of water pumped at the BSEP from 1977 through 2000.**

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